GEOLOGY OF THE
CENTRAL LITTLE BURRO MOUNTAINS
GRANT COUNTY, NEW MEXICO

by

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ABSTRACT

The Little Burro Mountains are a small fault-block mountain range in central Grant County, New Mexico. Rocks of the Precambrian Burro Mountains batholith are exposed along the southwest scarp of the mountains, and are overlain by Upper (?) Cretaceous Beartooth quartzite and Colorado shale. Faunal evidence indicates the Colorado to be of Turonian age. Above the Cretaceous strata is a thick sequence of Tertiary volcanic rocks. A blanket of Pleistocene and Recent poorly consolidated gravels and conglomerates covered the area, but has been partly removed as a result of uplift along the Mangas fault, which forms the steep scarp bounding the southwest side of the range. Strata dip northeast from the Mangas fault. Fissure veins containing gold, silver, manganese, lead, and copper traverse the granitic rocks of the batholith, and, locally, the Tertiary volcanics. Many small mining operations have been carried out in the past.

INTRODUCTION

The Little Burro Mountains, in central Grant County, New Mexico, is a fault-block mountain range of Precambrian, Cretaceous, and Tertiary rocks uplifted along a normal fault.

The area is in part traversed by ore-bearing veins which have attracted some mining activity in the past.

Economic interest in the geology of Grant County dates from the late Eighteenth and early Nineteenth Centuries. Copper mining, under the auspices of the government of Spain was inaugurated in the Santa Rita district in the year 1804. This activity, several miles east of the Little Burro Mountains, was mentioned by Lt. Zebulon Pike in his report of the expedition of 1807.

Little is known of the history of the economic development of the Little Burro Mountains themselves. Activity must have been near its peak when Sidney Paige visited the area in 1911, preparatory to writing the Silver City folio for the U. S. Geological Survey (1916). Since that time operations have waned, until at present there is no mining in the area.

The area included in this report (Fig. 1) comprises about 18 to 19 square miles in the central part of the Little Burro Mountains, and includes parts of Townships 18 South and 19 South, and Ranges 14 West and 15 West. New Mexico Highway 180 bounds the area on the southeast, and U. S. Highway 260 lies about two miles north of the area. The Mangas Valley road is the southwest boundary of the area.

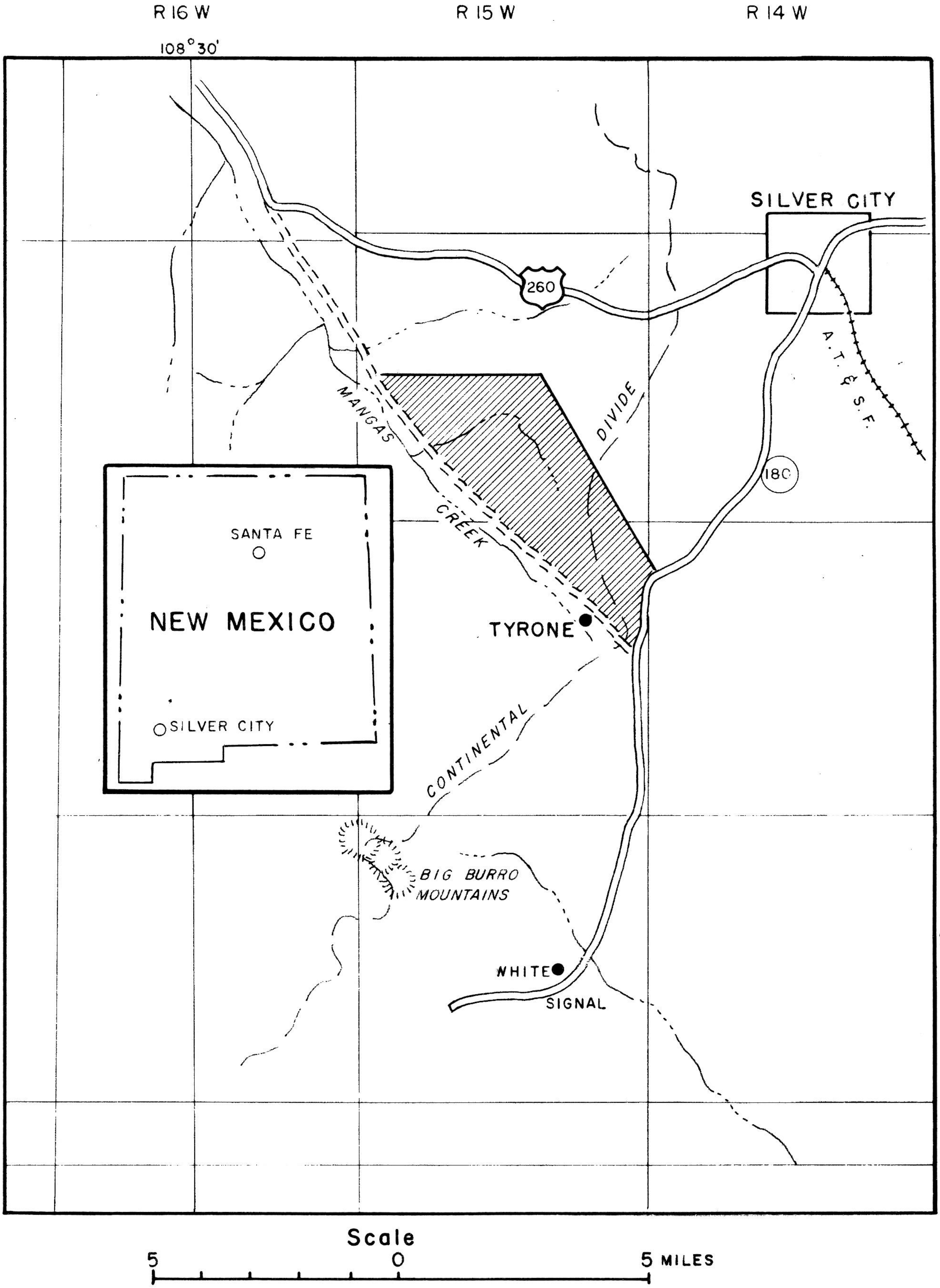


Figure 1. Location of the area. Cross-hatching indicates area mapped.

Tyrone, New Mexico, is on the southwest edge of the area, on the Mangas Valley road. Silver City, a town of 8,000 persons and the county seat lies ten miles northeast of the Little Burro Mountains.

Relief in the Little Burro Mountains is moderate. The highest measured elevation in the mapped area, 6,439 feet, is in the southeast, and the lowest, 5,285 feet, is near the Mangas Valley road in the northwest. Physiographically, the region is divisable into two units: the low, rolling, incised plain and terrace developed on the poorly consolidated, horizontally bedded gravels and sands of Pleistocene and Recent age (Fig. 2). and the mountainous terrain developed on the Precambrian, Cretaceous, and Tertiary rocks. The mountains reflect the structure of the underlying rocks. They are asymmetrical with a relatively steep scarp, the expression of the Mangas fault, on the southwest side. The northeast side has a much more gentle slope. The more resistant Precambrian rocks and the Beartooth quartzite form topographic highs. The Cretaceous Colorado shale, and several Tertiary tuffs are less resistant, and typically form topographic lows (Fig. 3).

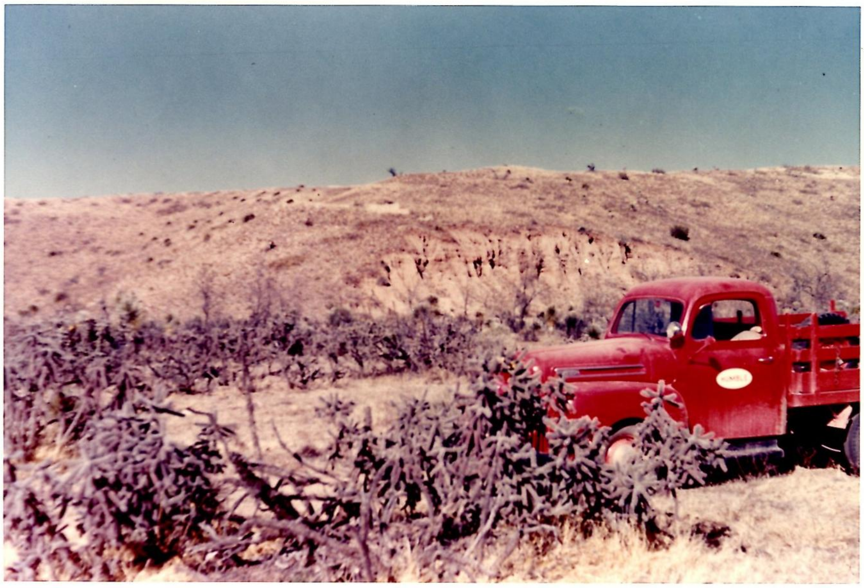


Figure 2. Exposure of the gravels of Pleistocene and Recent age about one-half mile west of the mouth of Redrock Canyon. Note the horizontal bedding of the gravels, and the gently rounded topography developed on this poorly resistant material. The camera faces north.

There are no perennial streams in the area, but several of the intermittent streams have developed large draws and canyons. Mangas Creek, which flows along the western and southwestern boundary of the area, is the largest stream in the area; it is an active watercourse only following heavy rains.

Redrock Canyon, which drains a major portion of the Little Burro Mountains, is a subsequent stream tributary to the Mangas Creek, and has developed on the outcrop of the

Colorado shale. It divides the central part of the mountains into two large ridges which parallel the northwesterly structural trend of the area (Fig. 3).

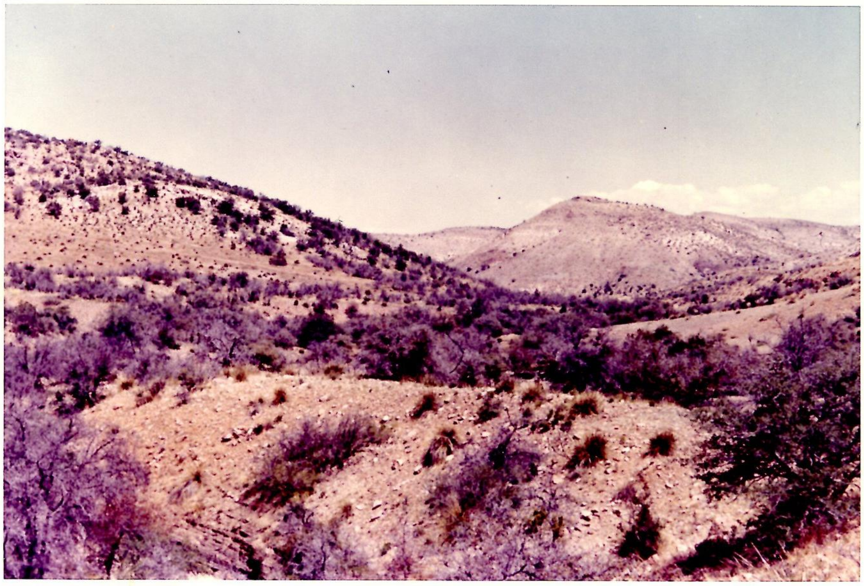


Figure 3. View northwest along Redrock Canyon from the foot of Bald Mountain. The Colorado shale outcrops in the foreground; the Beartooth quartzite supports the slope on the left. The hill in the distance is composed of volcanic rocks of Tertiary age. All strata dip to the right.

The climate is semi-arid, with an annual rainfall of 15 to 16 inches. Most of the precipitation occurs during the well defined rainy season which begins about the first of July, and lasts through September. Temperatures are not extreme, but the diurnal variation is marked, as is typical of an elevated, semi-arid region.

Three months of the summer of 1958 were devoted to field investigations. Field mapping was done on U. S. Geological Survey aerial photographs which had been enlarged to an approximate scale of 1:12,000. Data were transferred from these photographs to enlargements of parts of the Tyrone and Wind Mountain 7½ minute quadrangles by means of a Focalmatic Desk Projector, and the resulting map was reduced to a scale of 1:24,000.

PREVIOUS WORK

The general geology of the central Little Burro Mountains was first described by Paige (1916) as a part of the Silver City folio. Little else has been published directly concerning the area. Paige (1911) had previously made note of some of the mining activity in an investigation of mineral deposits in the Burro Mountains area. Also, he briefly mentioned the geology of the Little Burro Mountains in his study of the Tyrone copper district (1922). Gillerman (1952) discussed the geology of the Big and Little Burro Mountains in relation to fluorspar deposits. The area was visited by the Fourth Field Conference of the New Mexico Geological Society in 1953, and is discussed in the guidebook for that conference (New Mexico Geological Society, 1953).

ACKNOWLEDGMENTS

The writer would like to thank Elliot Gillerman for suggesting the area for study, and for his supervision both in the field and in the laboratory. Thanks are extended to Keith Young, of the Department of Geology, University of Texas, for assistance with the paleontological identifications. Mr. and Mrs. C. S. Woodward, whose ranch covers part of the mapped area, were most kind to the writer during his stay in the area, not only in their warm hospitality, but in supplying considerable information concerning access, mining, and history.

STRATIGRAPHY

Precambrian crystalline rocks, and Cretaceous, Tertiary, and Quaternary layered rocks are present in the Little Burro Mountains (Plate 1). Missing from the section in this area are the Paleozoic and lower Mesozoic strata which overlie the Precambrian in the Silver City range to the northeast, and in the Santa Rita mining district to the east.

Outcrops are generally good, and four sections were measured and described (Appendix).

Precambrian

Rocks of Precambrian age are exposed along the northeast side of the Mangas fault, in fault contact with Quaternary gravels and sands. Two major and one minor rock units were distinguished: (1) metamorphic rocks; (2) granite and related intrusive rocks of the Burro Mountains batholith; (3) minor aplite and sparse pegmatite dikes intruding the other rock types.

Metamorphic Rocks

A large mass of metamorphic rocks of varied nature occurs within the intrusive rocks of the batholith. It crops out along the Mangas fault near the center of the area. These metamorphic rocks, perhaps representing a roof pendant in the batholith, are characterized by dark colors, in comparison with the lighter colored acid rocks of the batholith. Outcrops of the metamorphic rocks are generally dark gray except where stained brown by iron oxides. Most outcrops are massive, showing no foliation.

Field relationships of the metamorphic sequence have not been studied in detail, and the relative abundance of the various rock-types is not known. However, three specimens have been selected for study as being generally representative of the main sequence of metamorphic rocks.

The first of these is a dark gray, dense amphibolite near the Mangas fault in the SE¼ of Sec. 28, T. 18 S., R. 15 W. Sparse calcite veinlets one millimeter and less in width are present on the brown, iron oxide stained outcrop. These veinlets are usually widely spaced (one to two feet), and may be followed for two to three feet across the outcrop.

Microscopic study of the amphibolite shows it to contain approximately equal amounts of xenoblastic hornblende and andesine (An_{25}) comprising 96% of the rock and minor amounts of magnetite (Fig. 4). The andesine locally shows cloudy alteration. The texture is granoblastic.

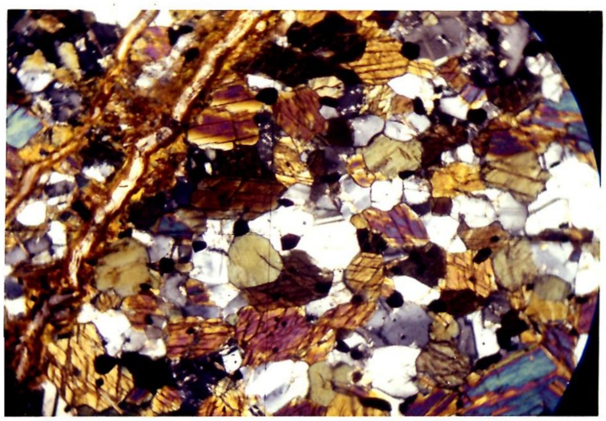


Figure 4. Amphibolite. The green and brown grains on which traces of cleavage planes are visible are hornblende; the blue-gray striated grains are andesine (An_{25}). The small, opaque areas are grains of magnetite. Note the pair of calcite veinlets surrounded by limonite staining. X40, crossed nicols.

The second metamorphic rock selected for study is a sillimanite (?) knotted schist which crops out about 1,000 feet southwest of the Snowflake Mine. This gray and gray-brown rock weathers brown, with extensive iron oxide stain on the outcrop. The sillimanite (?) is concentrated in knots or clusters which are more resistant to weathering than the remainder of the rock, and tend to stand out as roughly hemispherical knobs about two centimeters in diameter on the weathered surface.

Microscopic investigation shows this rock to be composed of 25% anhedral quartz grains about 0.7 millimeters in diameter, 30% pleochroic biotite flakes, 15% muscovite flakes, and about 20% a finely fibrous mineral which is probably sillimanite (Fig. 5). The sillimanite (?) occurs in clusters as finely fibrous, curved needles which are included in surrounding grains of quartz and mica. Around these knots of sillimanite (?) are zones of high biotite concentration.

The third metamorphic rock chosen for study is a quartz biotite hornfels cropping out about 1,500 feet southwest of the Jersey Lily Mine. This dark gray-green rock weathers brown, with extensive iron oxide stain developed on the outcrop. A faint planar element visible on the outcrop and in hand specimen suggests schistosity, but microscopic study

Figure 5. Sillimanite (?) knotted schist. The sillimanite (?) is the finely fibrous, curvilinear, brown and gray mineral in the lower right corner. The remainder of the rock is pleochroic brown and green biotite, clear anhedral quartz, and some muscovite and plagioclase (?) X40, crossed nicols.

reveals no orientation of mineral grains. The hornfels consists of about 95% fine (0.2 to 0.4 millimeters in diameter) quartz and biotite grains in nearly equal proportion. Small amounts of muscovite are present, and chlorite occurs as an alteration of the biotite. The texture of the rock is xenoblastic-granular.

Granite and Related Rocks

Granite and related rocks of the Burro Mountains batholith (Gillerman, 1956) crop out along the southwest part of the Little Burro Mountains from Cedar Canyon north to a point one-quarter of a mile northwest of the mouth of Redrock Canyon.

In the northern portion of its outcrop the rock is a pink, medium-grained granite containing abundant quartz and potash feldspar, and some biotite. Near the Mangas fault this rock is heavily fractured, and contains many veinlets of red iron oxide.

In the southern portion of its outcrop, the rock of the batholith is quartz monzonitic in composition, with as much as 50% of the total feldspar being albite (An_5), and is medium to fine-grained. The potash feldspar is microcline, and quartz is abundant. Most feldspar grains show cloudy alteration, and fine fractures in the rock contain a black material similar to the manganese oxides of the Contact Mine.

Intruding the metamorphic mass near the Woodward Ranch is a coarse-grained biotite quartz diorite porphyry, which has a mottled gray and black appearance on the outcrop, and weathers a gray-brown due to iron oxide stain.

The porphyry is composed of about 20% anedral to subhedral oligoclase (An_{20}) phenocrysts as much as 6 millimeters in diameter, and biotite grains to 3 millimeters in maximum dimension, in a matrix of anhedral quartz grains about one millimeter in diameter (Fig. 6). The twinning striae of the oligoclase are not visible in the hand specimen, and it has the same color as orthoclase.

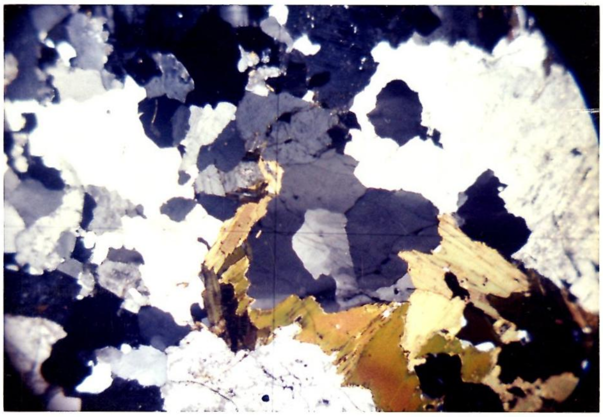


Figure 6. Biotite quartz diorite porphyry in contact with aplite dike. Porphyry (right two-thirds of the picture): quartz, and oligoclase with faint twinning striae appear blue in this photomicrograph; pleochroic brown and green biotite is easily recognized. Aplite (left one-third of the picture): quartz, and microcline, with some plagioclase and biotite. X40, crossed nicols.

The biotite quartz diorite porphyry, in the form of a small irregular stock less than 500 feet in diameter, is similar to the quartz diorite gneiss of the Black Hawk mining district 9 miles northwest (Gillerman, 1956), except that no preferred orientation of mineral grains was observed.

Small (generally less than one foot wide) aplite dikes traverse the biotite quartz diorite porphyry, and may be followed for more than one hundred feet across the outcrop before being covered by float.

Minor Intrusive Rocks

Many small (generally less than one foot wide) granitic dikes intrude only the Precambrian metamorphic mass and the intrusive rocks of the Burro Mountains batholith. These are largely granitic or quartz monzonitic in composition, and are similar to the main mass of the Burro Mountains batholith. The majority of these dikes are pink to gray, fine-grained, hypidiomorphic-granular rocks, consisting of from 40% to 70% orthoclase and/or microcline, 15% to 20% anhedral quartz, and varying amounts of plagioclases. The major accessory mineral is biotite (Fig. 6). The texture of the dikes is largely aplitic, but pegmatitic texture is present in some dikes.

Cretaceous System

Beartooth Quartzite

Directly overlying the Precambrian intrusive and metamorphic rocks in the Little Burro Mountains is the Beartooth quartzite of Late (?) Cretaceous age (Spencer and Paige, 1935).

The Beartooth quartzite is well exposed in the central part of the mountains, where it forms the rimrock of the range (Fig. 7), and on the western side of Redrock Canyon, which is a dip slope formed by stripping of the more easily eroded Colorado shale from the surface of the Beartooth quartzite. An isolated outlier of Beartooth quartzite is in the SE¼ of Sec. 21, T. 18 S., R. 15 W., just north of Redrock Canyon (Plate 2). Here the underlying granite is heavily altered and easily eroded, and the Beartooth quartzite forms the summit of a small hill.

Figure 7. The Beartooth quartzite (Cretaceous) overlying the Precambrian in the vicinity of the Snowflake mine. This is the "rimrock" of the mountain range. The camera faces northeast, and about 20° above the horizontal.

The Beartooth quartzite is composed of two to twelve feet thick beds of fine to medium-grained light gray quartzite separated in places by beds of sandy shale one to twelve inches thick. In many localities the quartzite is stained black. The quartzite is very hard and resistant, and generally forms ridges where exposed (Fig. 7). It has a subconchoidal fracture, and weathers in jagged, irregular blocks. Cross-bedding is locally developed (Fig. 8).

Figure 8. A weathered block of Beartooth quartzite. Note the rough, jagged appearance, and the cross-bedding visible on the weathered surface. The block stands about three and one-half feet high.

Microscopic study of the Beartooth quartzite shows it to be a mosaic of interlocking quartz grains from 0.5 millimeters to 5 millimeters in diameter. Hornblende is present in minute amounts (Fig. 9).

Figure 9. Fine-grained aspect of the Beartooth quartzite. The formation at this locality is an almost pure mosaic of interlocking quartz grains. X40, crossed nicols.

The thickness of the Beartooth quartzite in the Little Burro Mountains is 117 feet (Appendix).

The contact of the formation with the Precambrian is not well exposed in the area, but where seen it is a regular surface, and no basal conglomerate is developed in the quartzite.

The age of the Beartooth quartzite is in doubt. Paige (1916) considered it to be lithologically similar to the Dakota sandstone, and therefore tentatively dated it as Late Cretaceous. However, no fossils have been recovered from the formation anywhere in the Silver City area.

Colorado Shale

The Colorado shale, as identified in the Silver City area by Paige (1916), crops out along the length of Redrock Canyon and in the headwaters of Cedar Canyon.

The composition of the Colorado shale is variable. Brown, yellow, and gray fine to medium-grained sandstones alternate with gray and blue-gray, brown, black, and locally sandy shales. Sandstone and shale beds range in thickness from a few inches to several feet (Fig. 10). Sandstone composes approximately 30% to 50% of the formation.

Paige (1916) states that the maximum thickness of the formation is about 2,000 feet. In the Little Burro Mountains the maximum thickness measured was 156.6 feet (Appendix). The lower contact is an even surface on the Beartooth quartzite. Both sandstones and shales are in contact with the underlying formation.

The upper boundary of the formation in the Little Burro Mountains is an old erosion surface upon which flows of Tertiary andesite were extruded. These flows disturbed the upper surface of the shale, scouring and gouging it, and locally baking it (Fig. 11). Therefore, the sequence exposed in the mapped area represents only the lower portion of the formation, and an overlying sequence of unknown but probably great thickness has been stripped away.

Figure 10. Western aspect of Bald Mountain. The Colorado shale, dipping away from the camera, is exposed in the wash in the foreground. The entire Tertiary volcanic sequence is exposed on the side of Bald Mountain. The massive ridge one-half way up the slope is felsite agglomerate of the upper volcanic unit; the small ridge near the summit is the basalt unit. The camera faces almost due east.

Ammonites were found in the S½ of Sec. 35, T. 18 S., R. 15 W., 115 to 119 feet above the base of the Colorado shale. Five feet above the ammonite bearing zone a calcareous sandstone contains poorly preserved Gryphaea sp. cf. newberryi. The Grphyaea was also observed in the NW¼ of Sec. 27, T. 18 S.,

Figure 11. Colorado shale lower volcanic unit contact in the headwaters of Redrock Canyon. The overlying flow of the lower volcanic unit has gouged and scoured the upper surface of the Colorado shale. The shale has been slightly baked near the contact. Note the typically bleached, light brown color of the andesite, which is black when fresh. The strata are dipping away from and to the right of the camera, which faces east.

R. 15 W., but none were found below it at this locality. Fossils recovered from the ammonite bearing bed are:

<u>Kanabiceras n. sp aff. septimseriatim</u> (Crozier)

<u>Pseudaspidoceras sp. cf. footeanum</u> (Stoliczka)

<u>Romaniceras</u> (?) <u>sp.</u>

<u>Kanabiceras</u> (?) <u>sp.</u>

<u>Mebioceras sp.</u>

<u>Calycoceras</u> (?) <u>sp.</u>

<u>Inoceramus sp. cf. prefragilis</u>

This assemblage indicates a stratigraphic position just above the Vascoceras fauna of the Greenhorn limestone of Colorado and Kansas, in the lower Turonian (Keith Young, written communication, 1959). The Gryphaea zone is apparently widespread, as it is reported by Paige (1916) in the Silver City Range northwest of Silver City, and by Spencer and Paige (1935) in the Santa Rita Mining district.

Tertiary

Tertiary rocks of the Little Burro Mountains include lava flows and pyroclastics of a wide variety of compositions, and several intrusive bodies. The flows and pyroclastics have been divided, for the purpose of this paper, into four units: (1) a lower volcanic unit of andesite flows; (2) a middle volcanic unit of rhyolite, latite, and quartz latite tuffs; (3) an upper volcanic unit of felsite agglomerate at the base, with overlying tuffs resembling those of the middle volcanic unit; (4) a basalt unit of flows of vesicular olivine basalt porphyry.

Wargo (1959) has divided the volcanic rocks of southwestern New Mexico and southeastern Arizona into five major units (Fig. 12). It is difficult to determine how closely the

Unit	Main Rock Types	Distribution	Probable Age
A	Basalt flows	Mostly in intermontane valleys	Quaternary
B	Andesite, basalt and rhyolite with some interbedded sediments	Northern part of area. Probably most important group of 33rd parallel	Pliocene± Probably contemporaneous with many of the Gila gravels
C	Rhyolite, quartz latite with minor interbedded basalt andesite and sediments	Widespread. Found in almost every mountain range in the area	Late and Middle Tertiary
D	Andesite, latite	Widespread but erratic	Early Tertiary, some late Cret. Younger than widespread granodiorite-monz. intrusive phase in the area
	Granodiorite-monz.	Widespread	Tertiary-Cretaceous
E	Andesite, basalt, and latite interbedded with sediments	Best exposed in central and northern part of area	Some units in northern part are upper Cret. others in Central part are lower K. older than intrusive phase

Figure 12. Summary of Volcanic Stratigraphy of Southwestern New Mexico and Southeastern Arizona. Joseph G. Warge, 1959.

above classification correlates with Wargo's, but certain general comparisons may be made. On the basis of similarity of composition and stratigraphic position, it is suggested that the lower volcanic unit probably correlates with Wargo's Unit D, which he describes as "wide-spread but erratic." The middle and upper volcanic units by their similarity of composition and inclusions of sedimentary strata, probably correlate in part with Units C and B. Wargo notes the presence of basalts and andesites in Unit C, but none were found in the middle volcanic unit in the Little Burro Mountains. The writer places the base of the upper volcanic unit at the bottom of the felsite agglomerate flow, because this flow is a distinct, easily recognized marker bed in most parts of the area. It is impossible to determine if this boundary corresponds to the boundary between Units C and B. Unit A (basalt flows) seems to be represented in the Little Burro Mountains by the basalt unit.

The writer has tried to conform with established local usage of rock names where possible. Therefore, many of the rock names used in this section on Tertiary stratigraphy may appear incongruous with the specific mineral composition. Also, most of the pagioclase determinations were made by statistical methods, and, particularly in the pyroclastic rocks, may not represent the true composition of most of the plagioclases.

Lower Volcanic Unit

Unconformably overlying the Colorado shale, and in places gouging, scouring and baking its upper surface (Fig. 11), is a series of andesite and andesite porphyry flows. Commonly, the andesite is a dense, black rock, easily mistaken in the field for basalt. Throughout most of the area, however, it has been so heavily altered as to be nearly unrecognizable. Where altered, the andesite is a soft, easily weathered, brown rock exhibitng an exfoliation which lends it the appearance of shale. South of Indian Peak the andesite is lighter in color than in the northern part of its outcrop, and more obviously porphyritic (Fig. 13). Small (less than one millimeter in diameter) vesicles are locally present in the andesite, and the slight compositional difference between flows has been made visible by weathering on outcrops in the area south of Indian Peak. No baking of the lower part of the middle volcanic unit occurs at the contact with the lower volcanic unit.

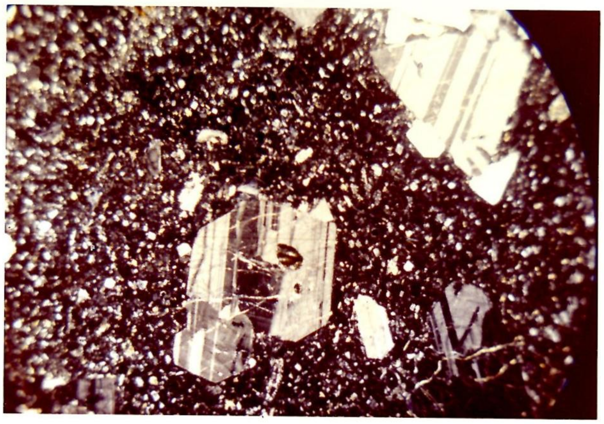


Figure 13. Andesite porphyry of the lower volcanic unit from the area south of Indian Peak. Large (2-plus millimeters) phenocrysts of euhedral oligoclase (An35) in a matrix which is largely glass. X40, crossed nicols.

The thickness of the lower volcanic unit is highly variable. The more than 700 feet difference in thickness between the two sides of the Cedar Canyon fault is one of the most marked variations (Plate 2). Near the center of the area, in Redrock Canyon, the unit is absent, and the middle volcanic unit rests directly on the Colorado shale. But, to the south, in the vicinity of Nigger Canyon, the lower volcanic unit exceeds 1,200 feet in thickness.

A representative specimen of the andesite of the lower volcanic unit is composed of from 60% to 75% oligoclase (An_{25}) as phenocrysts and microlites, and variable amounts of glassy material. Small amounts of fine-grained (0.1 millimeter and less in diameter) magnetite are present in all specimens.

Some of the specimens examined contain up to 15% penninite (Fig. 14). Much of the oligoclase shows cloudy alteration.

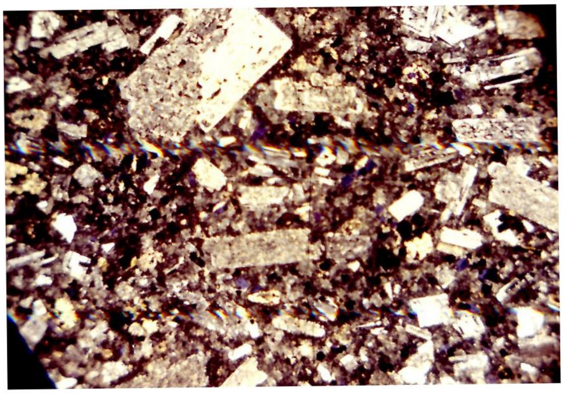


Figure 14. Andesite of the lower volcanic unit, from the area between Cedar and Nigger Canyons. Euhedral to subhedral phenocrysts of oligoclase ($Ab_{75}An_{25}$) in a matrix of plagioclase microlites and sparse penninite. The oligoclase is undergoing alteration to a clay-like mineral. X40, crossed nicols.

The age of the lower volcanic unit is not known. It is probably Late Cretaceous or Early Tertiary, and correlates with Unit D of Wargo (Fig. 12).

Middle Volcanic Unit

Above the andesite flows of the lower volcanic unit is a sequence of distinctive light colored tuffaceous rocks which has been designated the middle volcanic unit. It is composed of well-bedded rhyolite, latite, and quartz latite tuffs, many of which were deposited under subaqueous conditions, as shown by the rounded, detrital fragments they contain. Where exposed in the mapped area the middle volcanic unit is characterized by its well-bedded aspect and white and pink color. It is similar in many respects to part of the overlying upper volcanic unit, and the two units may be confused in the field if marker beds are not followed.

The tuffs of the middle volcanic unit are mostly glass, but have been given specific rock names on the basis of contained crystal fragments. Sanidine, plagioclases, quartz, and minor amounts of biotite are the important constituents of the crystal fraction. Many specimens exhibit cloudy alteration, the feldspars being the first minerals to be altered. Some strata contain rounded grains of quartz and microcrystalline, gray felsite, indicating that these strata are at least in part sedimentary in origin.

The middle volcanic unit is widely distributed in the Little Burro Mountains, and is between 310 and 430 feet thick within the area. Apparently, the unit is not restricted to the Little Burro Mountains, as rocks conforming to its description are reported by Paige (1916) in the side canyons of the Mimbres River, about 20 miles northeast of the Little Burro Mountains, and at several other localities.

The middle volcanic unit probably correlates with all or part of Unit C of Wargo (Fig. 12), and is Middle or Late Tertiary in age.

Upper Volcanic Unit

The upper volcanic unit also consists of a sequence of tuffs and agglomerates. It overlies the middle volcanic unit, and is similar to it in general aspect, but differs in containing mostly latites and quartz latites, with few rhyolites. The color of the weathered surface of the upper volcanic unit is similar to that of the middle volcanic unit, and the units are equally well-bedded.

The base of the upper volcanic unit is marked by a distinctive, 40 feet thick flow of felsite agglomerate, which is an excellent marker bed because of its dark color, resistance to weathering, and coarsely agglomeratic texture. It contains about 50% sub-angular to round fragments of dense, medium gray felsitic rock ranging from a few millimeters to 10 centimeters in diameter (Fig. 15). The matrix is vesicular, and consists of glass, some quartz and biotite grains, and extensive red iron oxide stain. The vesicles are 7 millimeters to 10 millimeters in average diameter, and occupy about 15% of

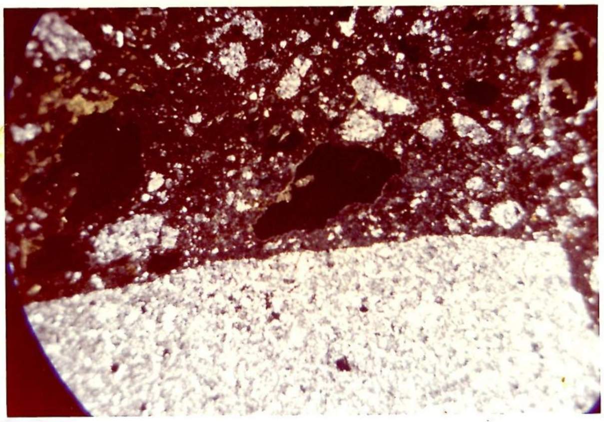


Figure 15. Felsite agglomerate. The large, mottled, blue-gray mass in the lower portion of the photomicrograph is a fragment of felsite; others occur in the upper portion of the picture. The large black areas are vesicles. X40, crossed nicols.

the rock. The felsite agglomerate is more resistant to weathering than the surrounding tuffs, and tends to form prominent ridges or cliffs where it crops out (Figs. 10 and 16).

Above the felsite agglomerate the upper volcanic unit is a relatively uniform succession of white and pink, well-bedded tuffs, containing some beds composed of rounded felsite fragments of probably detrital origin. A representative hand specimen of a pink bed in this sequence is a pink, medium-grained dacite tuff, containing white, altered feldspar grains, and gray rounded quartz grains in a very fine-grained pink matrix. Microscopic study shows it to be about 50% glass 10% andesine (An_{45}), and quartz and sanidine in amounts somewhat greater than 5%. Biotite is the major accessory mineral (Fig. 17).

Figure 16. Bald Mountain from the south, near the Contact mine. The distinctive ridge two-thirds of the way up the slope is formed by the felsite agglomerate at the base of the upper volcanic unit. The upper reaches of Redrock Canyon are in the middle distance to the left. The mountains in the distance are part of the Silver City Range. The camera faces slightly east of north.

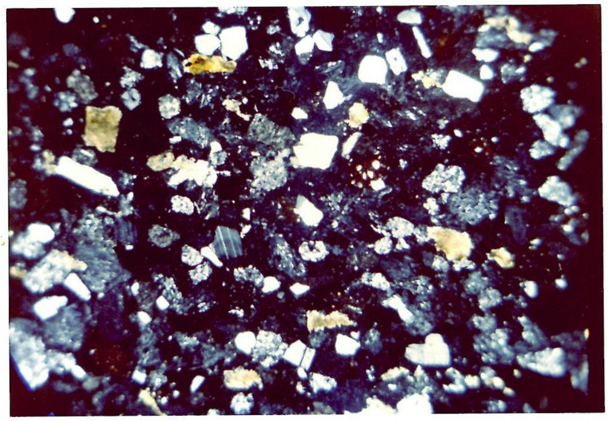


Figure 17. Dacite tuff of the upper volcanic unit. The rock consists of about 50% glass (dark), about 10% quartz and sanidine (both clear), and 10% andesine (An_{45}), which shows twinning striae. Several grains of biotite may also be seen in this photograph. X40, crossed nicols.

A hand specimen of a white bed in this sequence is very similar to the pink dacite, except that the matrix is white and chalky.

A dacite crystal tuff near the upper contact of the upper volcanic is present in the stream valley south of Indian Peak. This rock is also present in the northern part of the mapped area. In outcrop this rock is a dark pink, and tends to form ridges, probably due to its resistance to weathering. In hand specimen the dacite crystal tuff is a pink, dense rock with many angular feldspar grains visible on the surface. Microscopic study shows it to consist of about 40% glass, with sharply angular grains of andesine (An_{40}) and quartz, which respectively occupy 35% and 15% of the rock. Approximately 8%of the rock is sanidine, and minor amounts of magnetite and biotite are present (Fig. 18).

The greatest thickness of the upper volcanic unit measured was 948 feet (Appendix). The unit seems to maintain a nearly uniform thickness throughout the mapped area.

It is probable that the upper volcanic unit is Late Tertiary in age, and corresponds to Unit B of Wargo.

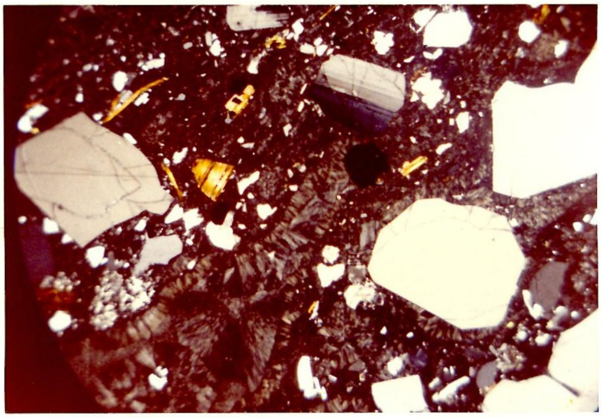


Figure 18. Dacite crystal tuff from the upper volcanic unit. Large (3 millimeters to 5 millimeters) grains of andesine (An_{40}) and quartz, with lesser amounts of sanidine and biotite in a matrix of devitrifying glass. Some of the andesine grains are euhedral in shape, while others are shardlike and fragmental. Note the feathery devitrification of the glass. X40, crossed nicols.

Basalt Unit

A distinctive olivine basalt porphyry lies above the tuffs and agglomerates of the upper volcanic unit. This rock is not widely exposed in the mapped area, and is concealed by Pleistocene and Recent gravels and sands in many places. Where it crops out it is resistant to weathering, forming the summits of Bald Mountain and a similar hill 9,000 feet southeast of Bald Mountain. The base of the unit is not well exposed, but it seems to be a relatively smooth surface on the top of the upper volcanic unit.

The basalt is a hard, black, vesicular rock with sparse phenocrysts of olivine. It weathers dark brown and gray, and disintegrates into rough, angular blocks on weathering. The rock is composed of 70% 0.4 millimeter in diameter bytownite (An_{85}) grains and microlites, minor amounts of glass, and 10% to 15% subhedral olivine phenocrysts. Vesicles constitute 5% to 15% of the rock, and are from one to two millimeters in maximum dimension. The texture is hyalophitic-porphyritic. The olivine phenocrysts are from 0.5 to 1.5 millimeters in diameter, and are partially altered to brown, slightly pleochroic iddingsite. Some of the smaller olivine grains are entirely iddingsite (Figs. 19 and 20).

The thickness of the basalt unit is unkown, as nowhere was the top of the unit exposed. The greatest thickness measured was 160 feet (Appendix). Probably the basalt unit corresponds to part of Unit B of Wargo. However, it is possible that it is Quaternary in age, and corresponds to part of Unit A (Fig. 12).

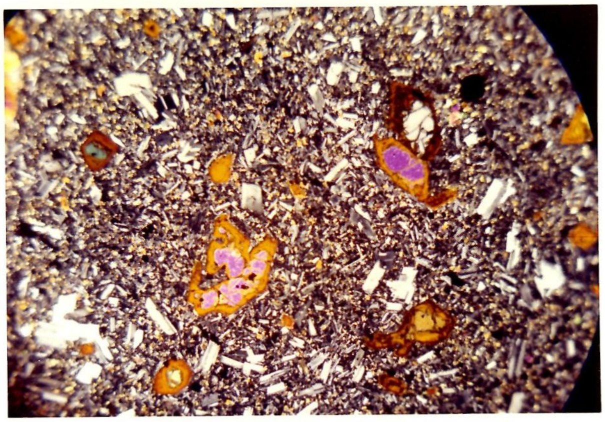


Figure 19. Olivine basalt porphyry of the basalt unit. About 70% of the rock is a felted mass of bytownite laths. Phenocrysts of olivine 0.5 millimeters to 1.5 millimeters in diameter are altering along cracks and grain boundaries to brown, pleochroic iddingsite. X40, crossed nicols.

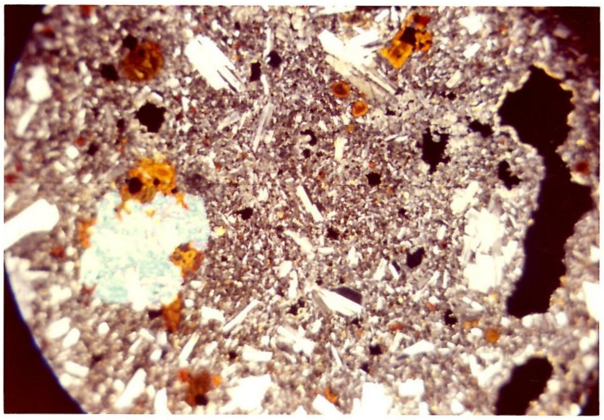


Figure 20. Olivine basalt porphyry from the basalt unit. Similar in constitution to the specimen shown in Fig. 19, but more vesicular. The three black areas near the right margin of the photomicrograph are vesicles. X40, crossed nicols.

Late Cretaceous and Tertiary Intrusive Rocks

Several dikes and irregular bodies intrude the lower volcanic unit and all older formations. Three of the largest of these have been mapped and investigated in detail:

1. In the N½ of Sec. 27, T. 18 S., R. 15 W., is a small altered sill composed of soft, green and gray platey minerals, and having a distinctive green coloration on the outcrop. This sill intrudes the Colorado shale, which is baked adjacent to both the upper and lower margins of the sill. The original character of the sill is difficult to determine because its constituent minerals have been extensively altered to a soft, easily eroded mass of chlorite and clay minerals, but it probably was originally hornblende diorite. The chlorite, probably an alteration product of hornblende and biotite, accounts for the distinctive green color of the rock. Masses of cloudy alteration product which seem to exhibit faint, relict twinning striae may represent plagioclase. Elongate masses of chlorite, prismatic in outline, suggest the prior existence of euhedral crystals of hornblende. Several one to two millimeter veinlets of calcite criss-cross the sill. (Fig. 21).

2. A possibly rhyolitic mass, irregular in shape, intrudes the Colorado shale and the lower volcanic unit in the headwaters of Redrock Canyon west of the base of Bald Mountain. In the southern part of the outcrop, this rock is a chalky appearing, very fine-grained material, probably rhyolite, which

Figure 21. Hornblende diorite (?) sill intruding the Colorado shale in Red Rock Canyon. Note the distinctive green coloring of the outcrop. The strata dip to the right. The camera faces west of north.

contains many fragments of baked Colorado shale and Beartooth quartzite. These fragments range in size from a few millimeters to 15 inches or more in diameter. Northwest of the fault which passes through the mass, the rock is composed largely of massive fragments of the Beartooth quartzite set in a matrix which is mostly glass, but which contains grains of quartz as much as 10 millimeters in diameter, some biotite, and as much as 20% calcite. The calcite occurs in small (0.2 to 0.5 millimeter in diameter) grains, which may represent recrystallized fragments derived from the calcareous strata of the underlying Colorado shale during intrusion. In places this rock consists almost entirely of quartzite fragments, with very little cementing matrix.

3. In the southern portion of the mapped area a large stock of quartz monzonite porphyry (Plate 2), the Little Burro Mountains stock, crops out both in the mapped area and south of New Mexico Highway 180. This stock is well exposed in the road cut of the highway (Fig. 22). The quartz monzonite

Figure 22. Exposure of the quartz monzonite porphyry of the Little Burro stock in the road cut of New Mexico Highway 180 near the continental divide at the southern boundary of the area. The camera faces north.

porphyry is a light gray rock, massive, and easily weathered. Under the microscope it is seen to have a fine-grained matrix of anhedral quartz and orthoclase, containing about 45% subhedral zoned phenocrysts of oligoclase (An_{10} to An_{30}) as large as 2.5 millimeters in diameter. Lesser amounts of anhedral quartz and orthoclase phenocrysts about 2 millimeters in diameter, and small amounts of biotite and traces of magnetite are present. In some of the specimens examined the matrix is microcrystalline, suggesting that these specimens were taken from localitite near the margin of the stock (Fig. 23).

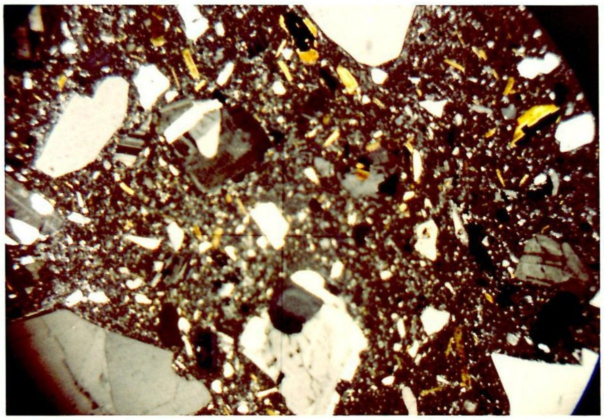


Figure 23. Quartz monzonite porphyry of the Little Burro Mountains stock. Subhedral phenocrysts of striated and zoned oligoclase (An_{10} to An_{30}) as large as 2.5 millimeters in diameter, with somewhat smaller phenocrysts of clear, anhedral quartz and orthoclase in a matrix of microcrystalline material. Many small grains of brown biotite are also present. The fine-grained matrix of this specimen suggests that it is from a locality near the margin of the stock. X40, crossed nicols.

The Little Burro Mountains stock is considered to be Late Cretaceous or Early Tertiary in age on the basis of its compositional similarity to other intrusive bodies in the Silver City area (Paige, 1916; Gillerman, 1956, Fig. 12). No contacts with surrounding rocks were observed in the Little Burro Mountains.

Pleistocene and Recent

Unconsolidated, slightly cemented, and easily eroded sands and gravels rest on units as low in the sequence as the lower volcanic unit, and are in fault contact with the Precambrian rocks (Fig. 24). They form a blanket entirely surrounding the mountains, and through which the older rocks project.

Figure 24. The contact of the Precambrian granite with the horizontally bedded Pleistocene and Recent gravels, sands, and semiconsolidated conglomerates at the Mangas fault, near the mouth of Redrock Canyon. The fault dips 63° SW at this locality. The camera faces southeast.

The sands and gravels are distinctly bedded where eroded in cutbanks or exposed in road cuts (Fig. 2). West and southwest of the Mangas fault the bedding is horizontal; north and east of the fault the sands and gravels dip concordantly with the older strata. The sands and gravels consist of fragments, ranging in size from very fine grains to large boulder, of Precambrian granite and metamorphic rocks, Cretaceous sediments, and Tertiary flow and pyroclastic rocks.

The exact age of the unconsolidated materials is difficult to determine, but they are probably younger than the Gila conglomerate (Pliocene-Pleistocene) of surrounding areas (Gillerman, 1956).

STRUCTURAL GEOLOGY

Two major patterns of normal faulting are recognized in the Little Burro Mountains (Plate 2); one trending northwest, the other trending generally northeast.

The northwest trending fault pattern is represented by the Mangas fault, the most prominent structural feature of the area and the boundary fault of the Little Burro Mountains east-tilted fault block. The Mangas fault trends about N 30° W, and dips 60° SW (Plate 2). In the southern part of the mapped area the trend is N 40° W, but, toward the northwest, the trend swings more northerly, and is about N 20° W near the northern boundary of the mapped area.

The Mangas fault is not a single fracture, but a series of subparallel fractures along which movement has taken place. The fault is easily distinguished on an aerial photograph because of the differences of color of the rocks on the two sides of the fault. It is, however, difficult to locate on the ground except in the gross aspect of its scarp. The fault zone can be seen in the adit of the Virtue mine (Plate 2), where horizontally bedded, unconsolidated gravels and sands, and semiconsolidated conglomerates of Pleistocene and Recent age are separated from altered, fractured Precambrian granite by a zone of gouge and breccia 12 feet wide. The gouge is dense, very dark red clay-like material. At this locality the fault dips 60° SW.

The thickness of the gravels on the downthrown side of the Mangas fault cannot be measured. Therefore, the total vertical displacement of the fault is unknown. Examination of the attitude of the rocks on the upthrown block, however, suggests a throw of not less than 1500 feet (note structural cross sections, Plate 2). Movement along the Mangas fault was post-Pleistocene (Fig. 24). Many silicified joints in the Precambrian Burro Mountains batholith parallel the trend of the Mangas fault, suggesting that the post-Pleistocene movement may have followed pre-existing lines of weakness.

The remainder of the faults all trend generally northeast, and have small er displacements than the Mangas fault. Few faults of this pattern show displacements in excess of 200 feet, and most show less.

The majority of the northeast trending faults are easily recognized and traced where they offset the Beartooth quartzite or the Colorado shale (Fig. 25), but become difficult to trace

Figure 25. Small fault in the headwaters of Redrock Canyon near the center of Sec. 35, T. 18 S., R. 15 W. The altered, bleached andesite of the lower volcanic unit is on the right; the dark gray shales of the Colorado shale are on the left. The camera faces northeast, along the strike of the fault.

where they traverse the Tertiary volcanics. Many do not disturb rocks above the lower volcanic unit, but a few offset units as high in the sequence as the basalt unit. With one exception, faults of this system are terminated by the Mangas fault. A few show distinct drag-folding (Fig. 26).

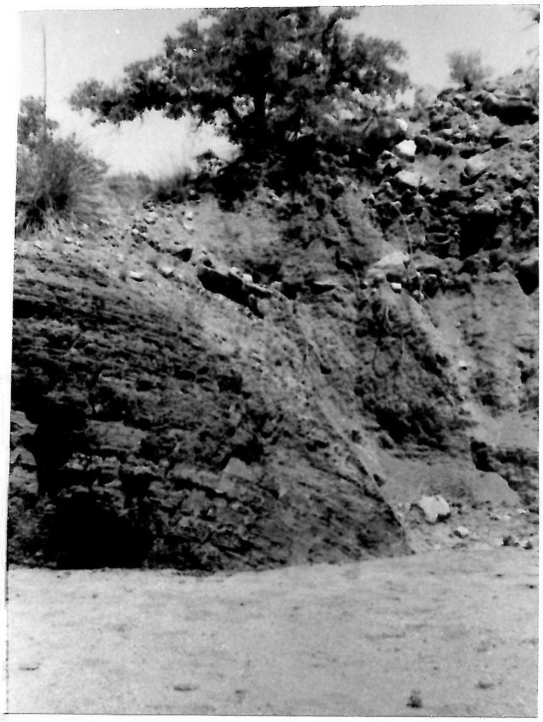


Figure 26. Drag-folding on a small fault in the Colorado shale at the bottom of Redrock Canyon near the middle volcanic unit quarry. The camera faces northeast, along the strike of the fault.

The only fault of the Little Burro Mountains which displaces the Mangas fault is the Indian Peak fault, which trends northeast across the northwest flank of Indian Peak (Plate 2). The Indian Peak fault intersects the Mangas fault about one mile north of the town of Tyrone, and offsets the northern portion of the mountains 150 feet to the southwest. This fault cannot be traced through the Pleistocene and Recent gravels of the Mangas Valley; but, because of its age and trend, it seems possible that it may be related to the Burro

Chief fault of the Tyrone mining district (Paige, 1922; Gillerman, 1956).

With the exception of the Indian Peak fault, all the northeast trending faults seem to have been active prior to movement on the Mangas fault. Evidence for this is the difference in thickness of the lower volcanic unit on the two sides of the Cedar Canyon fault and other northeast trending faults. Movement on the Cedar Canyon fault took place before the extrusion of the tuffs of the middle volcanic unit, or possibly during extrusion of the lower volcanic unit andesites. Many of these faults do not displace the upper volcanic and basalt units or the Quaternary gravels. The trend of faulting was established in Precambrian time, and repeated movement as late as Quaternary is shown by some faults.

ECONOMIC GEOLOGY

Exploitation of the mineral deposits of the Little Burro Mountains has been centered largely where the quartz fissure veins traverse the Precambrian granite of the Burro Mountains batholith on the western side of the range. Mining in this area has been sporadic, but it was at its peak in the early part of the Twentieth Century.

Four major veins are discussed by Paige (1916); and two smaller veins, along which the Snowflake and Jersey Lily mines are located, lie northwest of the area mentioned by Paige.

The Contact mine (Fig. 27) is along a normal fault striking generally north. The Virtue vein, to the south, is along the same fault. Minerals noted in the Contact vein include pyrite, chalcopyrite, a mixture of manganese oxides, and

Figure 27. The Contact mine. The pile of black material beside the headframe is manganese ore. Note the yellow and white color of the bleached and altered Precambrian granite exposed below and to the left of the headframe. The camera faces west.

finely disseminated silver and lead sulfide that is probably fine-grained argentiferous galena (Paige, 1911). Some gold was associated with the pyrite. Paige notes that the vein grows less distinct to the north, seeming to die out in a series of small fractures. The Contact mine was inactive during most of the period between 1915 and 1940, but was reopened during the early 1940's and mined for manganese. At this time the vein was followed to the south, until increasing copper content rendered mining uneconomical.

The Virtue mine is explored by a shaft and adit located near the intersection of the Contact fault with the Mangas fault. Free gold, and silver were produced from this mine, and total production reported is in the vicinity of $500,000 (C. S. Woodward, oral communication). The lower level of the mine is entered by an adit which crosses the Mangas fault, affording an excellent exposure of the fault zone.

West of the Contact vein is the Wyman vein, a silicified fracture zone which has been worked largely by open-pit methods of small extent, and shallow shafts. Most of the production was from above 40 feet.

About three-fourths of a mile north of the Wyman mine is the Full Moon mine, probably located on the northern extension of the Wyman vein. During recent years, the Full Moon mine was mined by C. S. Woodward for lead. The ore mineral, galena, was disseminated in altered, bleached granite and in fractures associated with the vein.

The Casino vein is a silicified fault zone lying west of the Wyman vein. The fault is nearly vertical at the surface, but is reported to dip steeply east at depth. Production from this mine was small, and largely from a few rich streaks of free gold (Paige, 1911).

The Jersey Lily mine, about one and one-fourth miles northwest of the Casino mine, was operated for a short time for silver. The major ore mineral was cerargyrite. No information is available concerning the total production.

The Snowflake mine is a few thousand feet north of the Jersey Lily mine. Argentite, cerargyrite, and ruby silvers were mined. It is reported that about 250 tons of ore were produced from this property (C. S. Woodward, oral communication).

A small fluorite deposit, The Ace High, is located in the SE¼ Sec. 28, T. 18 S., R. 15 W., four and one-half miles northwest of the town of Tyrone, in Precambrian granite near the Mangas fault (Gillerman, 1952).

Portions of the well-bedded middle volcanic unit have been utilized for building stone in the Silver City area, and a small quarry is present in the SW¼ Sec. 27, T. 18 S., R. 15 W This stone, because of its attractive pink and white color, makes an interesting decorative material. Several buildings in Silver City are faced with the stone, and the quarry is still sporadically operated (Fig. 28).

Figure 28. Building stone quarry in the middle volcanic unit on the east side of Redrock Canyon. The camera faces northeast.

GEOLOGIC HISTORY

The earliest event in the history of the Little Burro Mountains of which a record still remains was the deposition of Precambrian sedimentary rocks. These rocks were regionally metamorphosed and intruded by the later Precambrian Burro Mountains batholith. Erosion, following the cooling of the magma, removed much of the metamorphic rocks, leaving only a few roof pendants and blocks enmeshed in the batholith.

No record, except that of erosion, remains in the Little Burro Mountains from the time of the batholith to the deposition of Cretaceous sediments. To the west, in the Big Burro Mountains, even Cretaceous sediments are absent. A few miles to the east and northeast, however, this interval is represented in part by several hundred feet of Paleozoic and Mesozoic strata (Paige, 1916). Two possible hypothese are suggested to explain the sequence of evens in the Little Burro Mountains during Paleozoic and Early Mesozoic time: 1. Either the Little Burro Mountains were part of a structurally positive element throughout Paleozoic and Early Mesozoic time, and received no sediments; or, 2. An unknown thickness of Paleozoic (and Mesozoic?) strata were deposited, and subsequently stripped from the area by pre-Beartooth uplift and erosion.

Spencer and Paige (1935) note that the base of the Beartooth quartzite is essentially flat, but that it was deposited in the Silver City area on rocks ranging in age from Precambrian to Permian. These pre-Cretaceous rocks must, therefore, have been uplifted, tilted, and eroded nearly to base level prior to the deposition of the Beartooth quartzite. The uplift is presumed to have been greatest to the west, and the Big Burro Mountains probably remained as a positive area during Cretaceous and Tertiary time. If so, the shoreline of the sea which deposited the Colorado shale must have been in the area just west of the Little Burro Mountains.

Following uplift and beveling of the pre-Cretaceous rocks, Late Cretaceous seas advanced over the area, and the Beartooth quartzite and the Colorado shale were deposited.

Uplift and erosion followed deposition of the Colorado shale, and, in Late Cretaceous or Early Tertiary time, andesitic lavas of the lower volcanic unit flowed out upon the erosion surface developed on the Cretaceous rocks in the Little Burro Mountains.

At about the same time the quartz monzonite Little Burro Mountains stock was intruded in the southern part of the mapped area.

Faulting was active, probably subsequent to the extrusion of the lower volcanic unit, as indicated by the great difference in thickness of the andesite on either side of the Cedar Canyon fault (Plate 2).

A long period of eruption and deposition of pyroclastic and flow rocks encompassing a wide area in southwestern New Mexico followed the extrusion of the lower volcanic unit. This period of intense vulcanism was accompanied and followed by normal faulting in the Little Burro Mountains, possibly in compensation for the removal of such a large volume of material from beneath the surface. Outpourings of basalts, possibly separated by a long erosion interval from the earlier volcanics, marked the end of igneous activity in the Little Burro Mountains.

During Quaternary time erosion of the surrounding mountain areas covered or partly covered the Little Burro Mountains with a thick sequence of sands and gravels. Uplift along the Mangas fault caused a northeast tilt of the Little Burro Mountains area, and the formation of the topographic high. Erosion resulted in the removal of these unconsolidated and semiconsolicated materials, and the consequent exposure of crystalline and layered rocks. This erosion in Recent time has given the mountains their present form.

REFERENCES CITED

GILLERMAN, Elliot, 1952, Fluorspar deposits of the Burro Mountains and vicinity, New Mexico: U. S. Geological Survey Bull. 937-f, p. 261-269.

----------, and Whitehead, D. V., 1956, Uranium bearing nickel-cobalt-native silver deposits in the Black Hawk district, Grant County, New Mexico: U. S. Geological Survey Bull. 1009-k, p. 283-294.

NEW MEXICO GEOLOGICAL SOCIETY, 1953, Guidebook of southwestern New Mexico: Fourth Field Conference.

PAIGE, Sidney, 1911, Metalliferous ore deposits near the Burro Mountains, Grant County, New Mexico: U. S. Geological Survey Bull. 470, p. 131-150.

----------, 1916, Silver City quadrangle, New Mexico: U. S. Geological Survey Geologic Atlas, folio 199.

----------, 1922, Copper deposits of the Tyrone district, New Mexico: U. S. Geological Survey Prof. Paper 122.

SPENCER, A. C., and Paige, Sidney, 1935, Geology of the Santa Rita mining area, New Mexico: U. S. Geological Survey Bull. 859, p. 1-63, plate 3.

WARGO, Joseph G., 1959, unpublished manuscript.

APPENDIX

Measured Section 1. From the intersection of the bottom of Redrock Canyon with the southern boundary of Sec. 27, T. 18 S., R. 15 W., along a line N38°E into Sec. 26, T. 18 S., R. 15 W. (Plate 2).

Thickness, feet

Tertiary

Upper volcanic unit (41 feet, top missing).

22. Felsite agglomerate. Dark red, irregular weathered surface. Large fragments of dense gray felsitic rock ½" to 3" in diameter contained in a dark red, vesicular matrix consisting largely of glass, some quartz and biotite grains, and extensive red stain 41

Middle volcanic unit (426 feet)

21. Rhyolite tuff. Light pink. Thin-bedded, parting easily along bedding planes 38.4

20. Felsite tuff. Massive, white, chalky. Fine-grained. Sub-conchoidal, blocky fracture 9

19. Dacite (?) tuff. Pink and white. Medium to fine-grained. Contains many gray, rounded grains of quartz and felsite suggesting a detrital environment. Composition variable, some beds being more resistant than others . . 18

18. Felsite tuff. White, with tinges of pink and green. Some rounded quartz (?) and felsite grains. 26.5

17. Latite tuff. Pink. Medium-bedded 4

16. Quartz latite. White, Phenocrysts of quartz in glassy matrix. 15

15. Rhyolite tuff. Pink. Many fine, rounded grains of felsite of quartz 5

14. Covered interval 8.3

	Thickness, feet
13. Quartz latite tuff-conglomerate. White and pink. Contains many fine-rounded quartz grains. Medium- to fine-bedded; exhibiting cross-bedding near base	45
12. Quartz latite tuff, similar to upper part of unit 13. White and pink, to yellow where weathered. Thin to thick-bedded	130
11. Rhyolite tuff. Mottled pink and white. Very soft . .	5
10. Covered interval	115

Cretaceous

Colorado shale (110.8 feet. Incomplete, bottom not exposed)

9. Sandstone. Yellow-brown and grey. Clear, angular to subangular quartz grains, with large amounts of brown iron oxides and powdery white cement. Well developed leesegang rings. Massive	60
8. Shale. Blue-gray. Thin-bedded, with sparse, thin, brown sandstone layers	6
7. Sandstone. Yellow-brown. Massive; interbedded with blue-gray and green shale	18
6. Shale. Blue-gray. Rounded, blocky weathering. Sandy. Medium-bedded.	5
5. Sandstone. Brown, with rounded weathering. Shaley. Massive, medium bedded	7
4. Shale. Gray. With thin, interbedded brown sandstone layers.	8.5
3. Shale. Blue-gray. Thin-bedded, fissile	2
2. Sandstone. Fine, clear quartz grains. Massive, with faint cross-bedding.	4.3
1. Sandstone. Brown and gray. Fine-grained. Thin-bedded	?

Measured Section 2. From the Mangas fault in the $E\frac{1}{2}$ of Sec. 11, T. 19 S., R. 15 W., along a line northeast to the $NW\frac{1}{4}$ of Sec. 12, T. 19 S., R. 15 W. (Plate 2).

Thickness, feet

Tertiary

Basalt unit (160 feet. Incomplete, top eroded)

14. Divine basalt porphyry. Black. Resistant; rough, blocky weathering. Phenocrysts of loivine 0.5 mm to 1.5 mm in diameter in matrix of felted plagioclase microlites. The olivine is altering to brown, pleochroic iddingsite 160

Upper volcanic unit (948 feet)

13. Quartz latite tuff. Very soft, white chalky. Resistant to erosion where silicified along joints 28

12. Covered interval 65

11. Dacite tuff. Gray-pink, weathering brown. Grains of sanidine and plagioclase visible, much quartz, about 40% glass. Medium grained 165

10. Tuffs, conglomerate-tuffs, etc. Overall color pink and white. Mostly latites, quartz latites, and some rhyolites. Near base quite conglomeratic. Agglomerate flow at base with fragments of gray felsite in matrix light-colored, soft material. Thin to thick-bedded 690

Middle volcanic unit (311.3 feet)

9. Rhyolite tuff. White to pale blue-gray. Some fine, rounded quartz grains. Thin-bedded. 20

8. Latite tuff. Pink. Medium to coarse quartz grains concentrated along bedding planes 2

7. Felsite tuff. White, very soft. Very fine-grained. Medium to thin-bedded 40.3

	Thickness, feet
6. Quartz latite tuff. Pink, with rounded grains of gray quartz or felsite. Medium-bedded	3.5
5. Rhyolite (?) tuff. Pink near top, white near base. Medium to thin-bedded, in places fissile.	50
4. Latite tuff. Pink. Grains of white, altered plagioclase visible in hand speciment. Medium grained. Well-bedded.	5.5
3. Felsite tuff. Pink to gray-green, soft. Thin-bedded.	10
Lower volcanic unit (180 feet. Incomplete, in contact with Mangas fault)	
2. Andesite porphyry. Black and dark gray. Some flow-lineated vesicles near base	173
1. Andesite porphyry. Medium to dark gray. Less vesicular than unit 2	7

Measured Section 3. In Cedar Canyon from the center of Sec. 2, T. 19 S., R. 15 W., along canyon bottom from Cretaceous/Precambrian contact northwest to the base of the Quaternary gravels (Plate 2).

Quaternary	
Quaternary unconsolidated gravels and sands	
9. Gravels and sands. Gray-pink and buff. Cobbles and pebbles of Precambrian, Cretaceous, and Tertiary rocks, with interstitial sand and silt. Unconsolidated or poorly consolidated; poorly sorted. Bedded, but bedding obscure	(?)
Tertiary	
Lower volcanic unit (242 feet)	
8. Andesite. Black and dense where fresh, light brown and soft where altered. Phenocrysts of andesine in a matrix of fine-grained, felted plagioclase laths	242

Thickness, feet

Cretaceous

Colorado shale (156.5 feet. Top disturbed and variable)

7. Shale. Brown and gray to black. Locally sandy. Interbedded with yellow-brown, medium-grained, cross-bedded sandstone layers from six inches to one foot thick	31
6. Sandstone. Gray. Medium-grained, calcareous. Locally abundant _Gryphaea sp. cf. newberryi_	1.5
5. Shale. Similar to unit 7	5
4. Shale and mudstone. Gray, rounded weathering. Calcareous. _Mebioceras sp._, _Kanabiceras sp._, _Pseudaspidoceras sp. cf. footeanum (Stoliczka)_, _Romaniceras (?) sp._, _Inoceramus sp. cf. perfragilis_, _Calycoceras (?) sp._	4
3. Shale. Dark gray and brown. Locally sandy. Thin interbedded layers of medium-grained brown and yellow-brown, cross-bedded sandstone	115

Beartooth quartzite (117 feet)

2. Quartzite. Locally heavily stained brown and black by iron and manganese oxides, but light gray where fresh. Mostly nearly pure fine- to medium quartz grains; locally conglomeratic. Thick to massive bedded; locally cross-bedded. Interbedded, gray and blue gray, and brown sandy shales, one to three feet thick	117

Precambrian

Granite

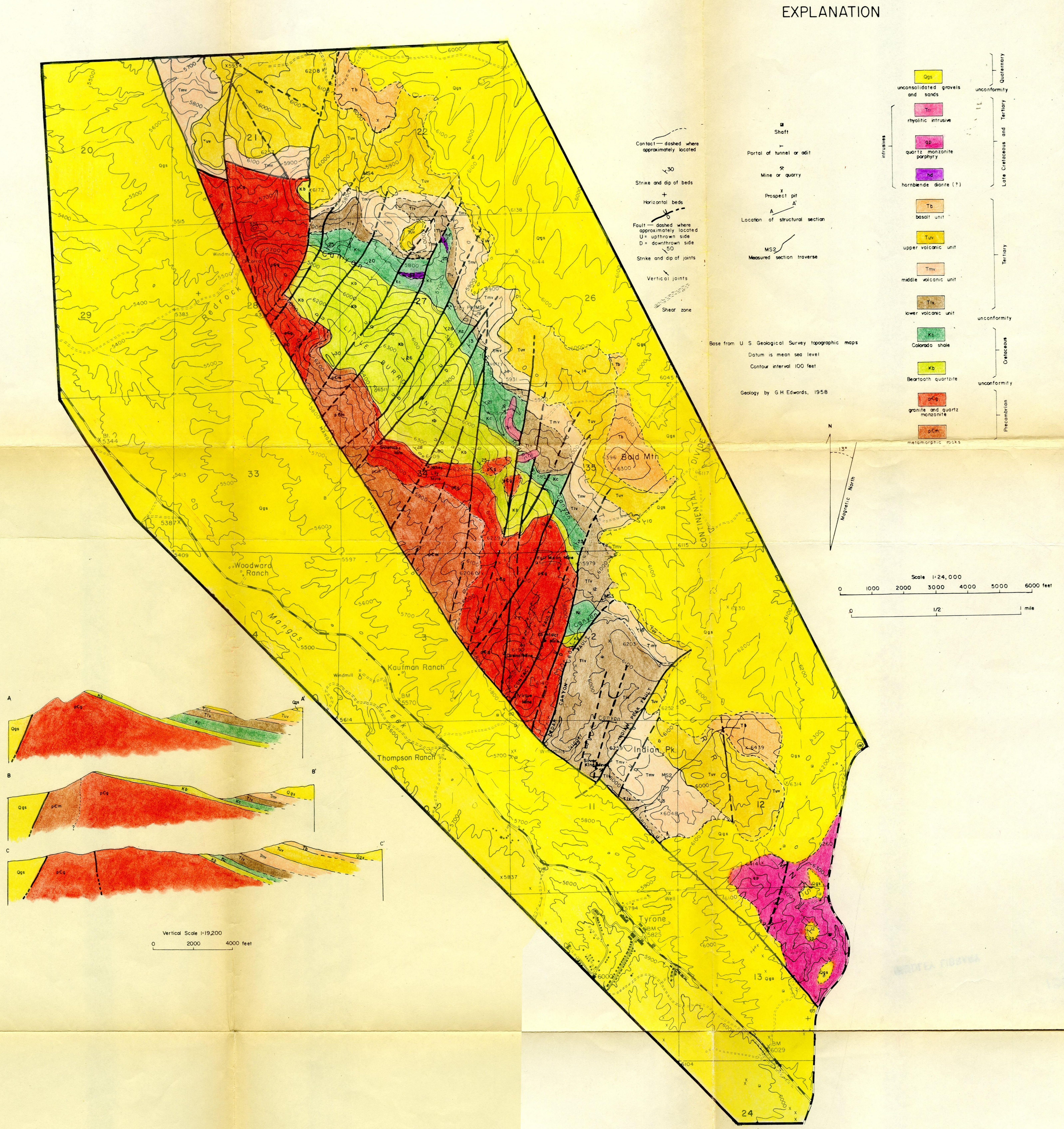
1. Granite. Yellow and gray, very soft and friable; easily weathered. Extensively altered.	?

Measured Section 4. From the bottom of Redrock Canyon in the NW$\frac{1}{4}$ of Sec. 27, T. 18 S., R. 15 W., along a line NNE to the N$\frac{1}{2}$ of Sec. 22, T. 18 S., R. 15 W. (Plate 2).

	Thickness, feet
Tertiary	
Basalt unit (91 feet. Incomplete)	
9. Olivine basalt porphyry. Black, dense, resistant; irregular, blocky weathering; weathers gray. Phenocrysts of olivine altering to iddingsite in a felted matrix of plagioclase laths.	91
Upper volcanic unit (763 feet)	
8. Tuffs. Light pink, locally pure white. Mostly latites, quartz latites, and some rhyolites. The sequence is mostly covered, preventing detailed study. Thickness by calculation	727
7. Felsite agglomerate. Dark red, irregular weathered surface. Large fragments of dense, very fine-grained felsite $\frac{1}{2}$" to 4" in diameter in a dark red, vesicular, glassy matrix. Extensive red iron oxide stain.	36
Middle volcanic unit (311 feet)	
6. (Rhyolite, latite, and quartz latite tuffs.) Interval mostly covered, except for a 6' layer of pink and white quartz latite directly underlying the felsite agglomerate of unit 7	311
Lower volcanic unit (96 feet)	
5. Andesite and andesite porphyry. Dark red and brown, poorly resistant. Heavily altered	96
Cretaceous	
Colorado shale (150 feet)	
4. Covered interval. Red-brown shale and fine-grained brown sandstone in float	51

	Thickness, feet
3. Sandstone. Gray-brown to pink-brown. Medium-grained; arkosic, with abundant weathered feldspar grains. Medium bedded	15
2. Shale. Gray; sandy. Interbedded with black, thin-bedded shale, and thin, fine-grained brown sandstone. Sandstone 6" to 1' thick near the top of the unit, cross-bedded	84
Beartooth quartzite (Base not exposed)	
1. Quartzite. Gray, dense, with extensive red and black stain. Medium to thick-bedded. Interbedded sparse, thin, gray shale	(?)

PLATE 2



GEOLOGIC MAP AND STRUCTURAL SECTIONS OF
THE CENTRAL LITTLE BURRO MOUNTAINS,
GRANT COUNTY, NEW MEXICO

GENERALIZED STRATIGRAPHIC SECTION